Resume of the proposed research topic on:

"Automatic Detection of Diabetic Retinopathy and Associated Diseases"

by

Panchal Sachin Devidas

Research Scholar

Under the guidance of

Dr. Manesh B. Kokare

Professor

Department of Electronics & Telecommunication Engineering,

S.G.G.S. Institute of Engineering and Technology,

Vishnupuri, Nanded – 431 606, INDIA.

E-mail: 2021pec202@sggs.ac.in , Phone No.: 9665602266

Table of Contents

Table of Contents 2

Abstract 1

1. Introduction 2

1.1 Structure of eye 2

1.1.1 Optic Disc 3

1.1.2 Blood Vessels 3

1.1.3 Macula and fovea 3

1.2 Types of Lesions in Diabetic Retinopathy 3

1.2.1 Microaneurysms 3

1.2.2 Exudates 4

1.2.3 Neovascularization 4

1.2.4 Hemorrhages 4

1.3 Grading of Diabetic Retinopathy 5

1.3.1 No DR 5

1.3.2 Mild DR 5

1.3.3 Moderate DR 5

1.3.4 Severe DR 5

1.3.5 PDR 5

1.4 Multi-diseases Retinopathy 5

2. Review of Literature and development in the subject. 7

3. Objectives of research 10

4. Methodology to be adopted 11

4.1 Materials 11

4.2 Methods 11

5. Importance of Study 13

6. Proposed work plan: 13

References 14

Abstract

Background: Diabetic Retinopathy (DR) is one of the threatening disease which is entered in top ten diseases which cause death around the world. In last decade there is tremendous growth in diabetic patients due to lifestyle, uncontrolled diet and genetic causes. Detecting and grading the severity of diabetic retinopathy at an early stage can save a vision of person.

Methods: Detection of abnormalities in the retinal fundus image may aid in the diagnosis and classification of the disease. As a result, the fundamental features of the retinal fundus image must be segmented and extracted, including the optic disc, optic cup, retinal blood vessels, and macula. By removing key elements from the sample image, abnormalities may be identified. The final image indicates the diagnosis of retinal diseases, which is useful for medical practitioners and representatives. In several domains, deep learning techniques have enabled computers to learn from massive datasets in ways that surpass human skills. Several datasets are available for detection of DR and multidiseases classifications. However, many researchers proposed several types of methods such as SVM, CNN, fuzzy logic for classification with good performance index.

Conclusions: Automated and validated model can be built that can provide real-time image quality feedback, detect retinal lesions, and grade DR from No to severe stages. Furthermore, research is needed to see how well a deep learning system can identify and predict the DR.

1. Introduction

In Recent past three years, patients having Diabetes mellitus (DM) is increasing in India. In India, among the 20 plus age population, there were an estimated 65 million people with DM in 2016. Assuming 15% - 20% of these individuals have any DR and 5% - 7% have vision-threatening DR, 3.25 - 4.55 million people are at risk of visual loss or have already lost vision from DR. This Equals to 2240 - 3136 people aged 20 years and above in a district of 1 million [1]. Worldwide there are more than 415 million people are affected, with approximately 1 of 11 adults being affected. By 2040, it is anticipated that approximately 600 million people will have DM [2]. By recent survey of WHO, Diabetes have stepped into top 10 causes of death. Since 2000, 80% of increase in death rate caused due to diabetes till 2019 in lower middle income countries. Age related macular degeneration is a leading course of blindness among the elderly in developed countries and recent research has suggested the prevalence of AMD to be 14.3% to 17.6% in those older than 65 years of age. Easiest method is to preprocess and extract feature for finding different diseases based in quantification of features. Mean value and standard deviation of normal fundus images and images having exudates, hemorrhages and micro-aneurysms are different for classification [3]. Diabetic retinopathy is mostly genetic disease that occur in most of the population genetically. It is categorized under two classes based on its severity. Non-proliferative diabetic retinopathy (NPDR) is the early stage of the disease in which symptoms will be mild or nonexistent. Proliferative diabetic retinopathy (PDR) is the severe stage of the disease. At this stage, circulation problems occur in the retinal oxygen which causes formation of new fragile blood vessels in the retina and into the vitreous of the eye. The new blood vessels may leak blood into the vitreous which further causes clouding in vision. It is like nightmare for the diabetic patients in developed countries in working age population [4].

1.1 Structure of eye

The retina is a layered structure that lines the inner surface of the eye. It consists of layers of neurons: light-sensitive photoreceptor cells, bipolar cells, horizontal cells, amacrine cells and retinal ganglion cells, which transmit the visual information to other parts of the visual system along the optic nerve. It consists of ten semi-transparent layers that serve specific functions in the process of visual perception [21].

1.1.1 Optic Disc

The optic disc is a collection of nerves that surround the optic cup. Vertically, it is somewhat elongated. The disc has a horizontal diameter of around 1.7 mm and a vertical diameter of about 1.9 mm [5].

1.1.2 Blood Vessels

The purpose of blood vessels is to transport blood to organs and tissues. Blood consist of oxygen and nutrients. They carry waste materials and carbon di oxide away from the organs and tissues. Because they do not utilized within any other system, retinal vessels are referred to as "end vessels" [5].

1.1.3 Macula and fovea

The Macula is located at the back side of eye. The macula is responsible for the central vision of eye. The fovea of the retina is a shallow depression in the middle of the macula. The retinal neurons are shifted, leaving just photoreceptors in the middle, resulting in this depression. The horizontal diameter of the fovea is around 1.5 mm [5].

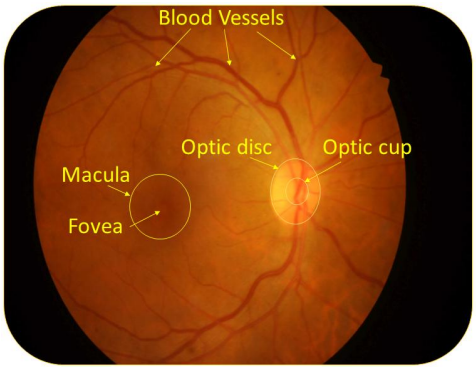

Figure1: structure of eye [6]

1.2 Types of Lesions in Diabetic Retinopathy

1.2.1 Microaneurysms

They are identified by ophthalmoscopy as deep-red dots varying from 25 to 100 µm in diameter and are usually the first visible sign of diabetic retinopathy. Microaneurysms arise as hypercellular saccular outpouchings of the capillary wall which can be well visualized in trypsin-digest retinal mounts. Their Lumina are sometimes occluded by agglutinated erythrocytes or thrombus [7].

1.2.2 Exudates

They appear as a bright lesion of varying size and shape in fundus image. The texture of the unhealthy part of the retinal image is irregular and it varies for different eyes as compared to the healthy part of the retinal image. Unhealthy part varies in size and texture and then it is always easy to segment healthy part of retinal image compare to unhealthy part [8].

1.2.3 Neovascularization

Neovascularization is the process of generating new blood vessels due to extensive lack of oxygen in the retinal capillaries. They are weak, easily torn in nature. It may cause loss of vision. Detection neovascularization in retinal image is really a challenging task for researcher since its similarity with normal blood vessels [9].

1.2.4 Hemorrhages

Retinal hemorrhage is abnormal bleeding from the blood vessels in the retina, backside of eye. The retina is the inside surface of the back of the eye consisting of millions of densely arranged, light-sensitive cells called rods and cones. These blood vessels can become damaged by injury and disease and may bleed (haemorrhage) and cause temporary or permanent loss of visual accuracy. Because the cells of the retina are so dense and sensitive, even small injuries to the blood vessels can translate into vision problems. Diseases that affect the health of the circulatory system, such as diabetes and high blood pressure, also affect the blood vessels of the eye. Damage to the blood vessels in the retina, including haemorrhage, is termed retinopathy [10].

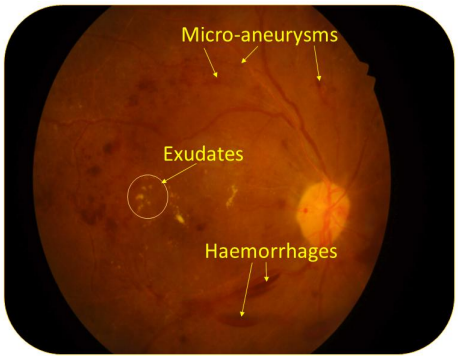

Figure 2: Lesions in diabetic retinopathy [6]

1.3 Grading of Diabetic Retinopathy

1.3.1 No DR

No Symptoms are observed

1.3.2 Mild DR

At least one microaneurysm is present in mild DR.

1.3.3 Moderate DR

More than just microaneurysms are present, which is somewhere between mild and severe NPDR.

1.3.4 Severe DR

One or more of the following, in the absence of PDR:

a. More than 20 intraretinal hemorrhages in each of four quadrants
b. Definite venous beading in two or more quadrants
c. Prominent Intra-Retinal Microvascular Abnormalities (IRMA) in one or more quadrants

1.3.5 PDR

One or more of the following:

d. Extra retinal neovascularization
e. Vitreous or pre-retinal haemorrhage

Figure 3: Severity grading in diabetic retinopathy

1.4 Multi-diseases Retinopathy

The main purpose of this research is to design and implement a Multi-Disease Classification model capable of detection of various of eye disorders using fundus

images for ophthalmic disease multi-class classification. The Retinal Fundus Multi-Disease Dataset (RFMiD) is a dataset that includes a wide range of images with several diseases. There are both common and unusual diseases in this dataset. The dataset consists of 3200 images, categorized into 46 labels. It is imbalance multi-label dataset with higher degree of imbalance ratio per label [11].

Section 2 discusses the literature review. The research objectives are specified in section three. In section 4, the methodology to be adapted, including materials and methods, is briefly discussed. The importance of the study on an international scale, as well as the national status of the study, are provided in section 5, and a year-by-year proposed work plan is offered in the last section.

2. Review of Literature and development in the subject.

A few year ago, Adrián Colomer et al. [2] implemented Local Binary Patterns (LBP) for texture classification. Also they have tested three different classifiers: random forests (RF), support vector machines (SVM) and Gaussian processes for classification (GPCs). The proposed method was performed on for the 45 retinal images which got average performance index on Sensitivity, Specificity, Accuracy as 75.61%, 75.62%, 83.44% for detection of Micro-aneurysms and Hemorrhages.

Bibi et al. [12] proposed a segmentation independent two-stage preprocessing based technique is proposed which can effectively extract DR pathognomonic signs; both bright and red lesions, and blood vessels from the eye fundus image. Then, the performance of Local Binary Patterns (LBP), Local Ternary Patterns (LTP), Dense Scale-Invariant Feature Transform (DSIFT) and Histogram of Oriented Gradients (HOG) as a feature descriptor for fundus images, is thoroughly analyzed. SVM kernel-based classifiers are trained and tested, using a 5-fold cross-validation scheme, on both newly acquired fundus image database from the local hospital and combined database created from the open-sourced available databases. The classification accuracy of 96.6% with 0.964 sensitivity and 0.969 specificity is achieved using a Cubic SVM classifier with LBP and LTP fused features for the local database. More importantly, in out-of-sample testing on the combined database, the model gives an accuracy of 95.21% with a sensitivity of 0.970 and specificity of 0.932.

Calleja et al. [13] presented a method for diabetic retinopathy detection. This method is divided into two stages: in the first one, we have used local binary patterns (LBP) to extract local features, while in the second stage, we have applied artificial neural networks, random forest and support vector machines for the detection task. Preliminary results show that random forest was the best classifier with 97.46% of accuracy, using a data set of 71 images.

Kanungo et al. [14] implemented the automated detection of diabetic retinopathy algorithm using common preprocessing techniques are normalization of the data, mean subtraction and Principle Component Analysis (PCA) which resulted into Sensitivity of 97%, Specificity of 87%, Accuracy of 88%.

Table 1: Performance Analysis of proposed methods of several authors in lesion detection in diabetic retinopathy.

Author	Objective	Proposed methods/ techniques	performance
Adrián Colomer et al.	detection of Micro-aneurysms and Hemorrhages	Local Binary Patterns LBP + Gaussian processes for classification GPCs	Sensitivity, Specificity, Accuracy as 75.61%, 75.62%, 83.44%
Bibi et al.	bright and red lesions, and blood vessels	Cubic SVM classifier with LBP and LTP fused features	Accuracy 96.6% with 0.964 sensitivity and 0.969 specificity
Calleja et al.	Detection of lesion	LBP + random forest	Accuracy 97.46%
Kanungo et al.	Detection of DR	PCA	Sensitivity of 97%, Specificity of 87%, Accuracy of 88%.

Deep Learning Approach

As per the WHO survey, DR and DME are most commonly observed diseases in working age population [8]. Undiagnosed DR and DME may lead to complete or partial blindness. The early detection of the eye related diseases may save vision of the subject. So, any eye related complaint should be concerned with expert ophthalmologists. Xiaomeng Li et al. [15] designed and implemented the Cross-disease Attention Network (CANet). The proposed method is consisting of disease specific and disease dependent attention modules. The disease specific attention module enhances the diseases related features and conquer the irrelevant features by obtaining spatial information from shared feature maps. The spatial information is then fed to the multilayer perception to get channel wise attention maps. Now, the disease specific features are passed through the pooling and CNN to produce disease dependent features. ResNet 50 is used for feature extraction. The network is trained on MESSIDOR and IDRiD datasets respectively.

The age related macula degeration

M. Mateen et al.[10] compared and summarized with the collection of retinal datasets, adoption of different kinds of methodologies to detect the diabetic retinopathy and select the performance evaluation metrics for the representation of their outcomes performance of traditional and deep learning approaches. They have found that accuracy of deep learning is far better that traditional approach. Detection of exudates

using deep learning CNN and ResNet-50 perform better with 98% accuracy than traditional approach with accuracy 93%. A. Momeni Pour et al. [16] The model is trained on a mixture of two Messidor-2 and IDRiD datasets and evaluated on the Messidor dataset. The Messidor-2 and Messidor datasets include DR labels with various levels for automatic DR detection. The Messidor-2 dataset includes 1,748 retinal color images of 874 subjects. Their model is able to achieve 92% sensitivity and 94.5% AUC in test data.

3. Objectives of research

RO1. To detect abnormalities in retina using retinal images with higher accuracy.

RO2. To propose an efficient algorithm for segmentation and detection of optic disk and blood vessels.

RO3. To classify and detect multiple diseases associated with retinopathy.

RO4. To implement and validate an algorithm based on deep learning to automatically diagnose plus detect disease from retinal photographs.

4. Methodology to be adopted

4.1 Materials

For research and development in the detection of diabetic retinopathy, several datasets are publicly available. Performance of machine learning model relies mostly on datasets and designed algorithm. The optic disc, blood vessels, macula, and fovea are clearly caught in retinal images of normal subjects, however abnormalities can be seen in images of subjects with eye illness. Dataset consists of both types of images. The images in training and validation sets are annotated by expert ophthalmologist. The ground truths are present for each dataset. The images along with their dimensions and number of samples present in dataset are presented in table.

Table 2: Several datasets used for detection of DR, grading DR, lesions, and multi-disease. The image dimension and number of images available for each dataset are indicated in the table.

Dataset	Images Dimensions	Number of samples	DR Grade	Lesion detection	Multi-disease
IDRiD [6]	4288x2848	516	Yes	Yes	No
DRIVE [17]	768x584, 565x584	40	Yes	Yes	No
MESSIDOR [18]	1440x460, 2240x1536	1748	Yes	Yes	No
DIARETDB [19]	1500x1152	89	Yes	Yes	No
DRIONS [20]	600x400	110	Yes	Yes	No
RFMiD [11]	2144x1424, 4288x2848, 2048,1536	3200	Yes (379 images)	Yes	Yes (46 diseases)

4.2 Methods

Deep-learning methods represent multiple levels of representations obtained by combining simple but non-linear modules that can transform the representation at one level into a representation at a higher, slightly more abstract level. A Learning

algorithm can be applied on an image composed of array of pixel values from which different features are to be extracted like edge detection and its location and orientation. Next to this to detect different patterns by spotting particular arrangements of edges, regardless of small variations in the edge positions. Lastly, combine all the detected patterns into single pattern which correspond to parts of familiar objects which determines combinations of these parts. This work aims to focus on methods proposed and implemented by authors and researchers to detect and identify abnormalities observed in retinopathy for implementing efficiency algorithm.

The flow of detection of diabetic retinopathy is represented in the figure. This includes Image acquisition, Image pre-processing, feature extraction, and the extracted features are used for detection, classification or segmentation.

Fundus camera

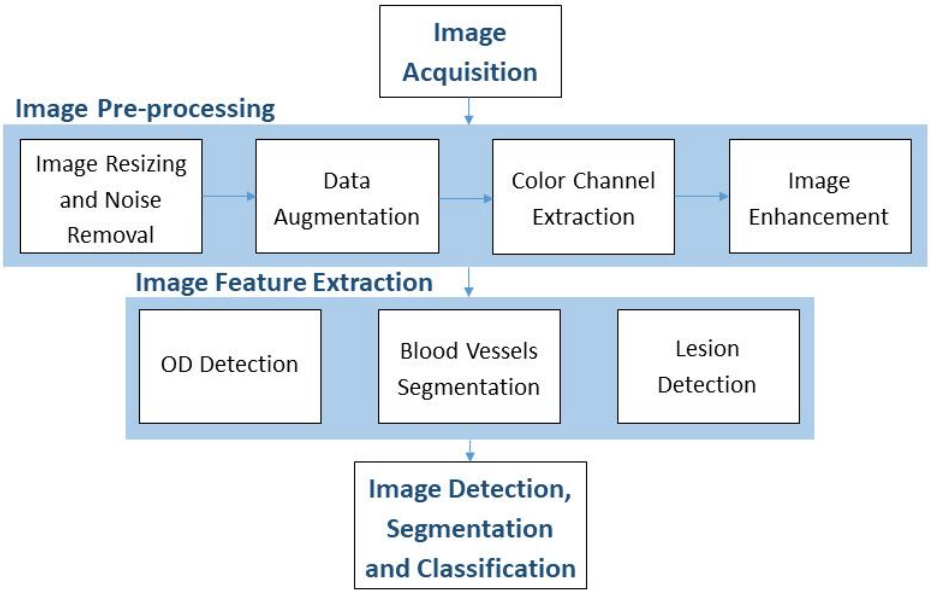

Figure 4: The flow of detection of diabetic retinopathy.

While training the model, the given dataset is divided into training and validation sets. The model is validated by determining how well it predicts output when compared to the ground truth. Validation set helps to improvise the performance by fine-tuning the hyper-parameters. The validated model then used to test performance on testing set.

5. Importance of Study

DR is a frequent consequence of diabetes mellitus that creates vision-impairing lesions on the retina. It can cause blindness if it is not diagnosed early. Unfortunately, DR is not a curable condition, and therapy simply keeps vision from deteriorating. Early identification and treatment of DR can lower the risk of vision loss significantly. Unlike computer-aided diagnosis systems, the manual diagnosis of DR retina fundus images by ophthalmologists is time consuming, inefficient as well as may lead to misdiagnosis. So early diagnosis in diabetic retinopathy and other retina related diseases may save the vision of patient. The computer aided diagnosis system give accurate diagnosis of disease in real time. This system will be helpful for medical representative and patients and will have high impact in biomedical engineering field and healthcare sector.

6. Proposed work plan:

Table 3: Year-wise Plan of Work and target to be achieved

Year	Work	Research Objectives	Target to be achieved
I (2021-22)	Literature Review, Tools understanding for problem solving, Learning new technologies, implementation of algorithms, Result analysis and Research article writing.	RO1	Journal Paper I
II (2022-23)	Working on Segmentation and detection of Optic disc and blood vessels, Working on data pre-processing on Multi-Label Imbalance dataset (MLD), Design and implement an algorithm on MLDs, Result analysis and Research article writing.	RO2 RO3	Conference Paper I Journal Paper II
III (2023-24)	Pre Ph.D. Synopsis Submission, Thesis writing, Thesis Submission	RO4	Conference Paper II / Book Chapter I

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Bhandare Mangesh Nagnath
Research Scholar

Dr. Ramachandra R. Manthalkar
Ph.D. Supervisor